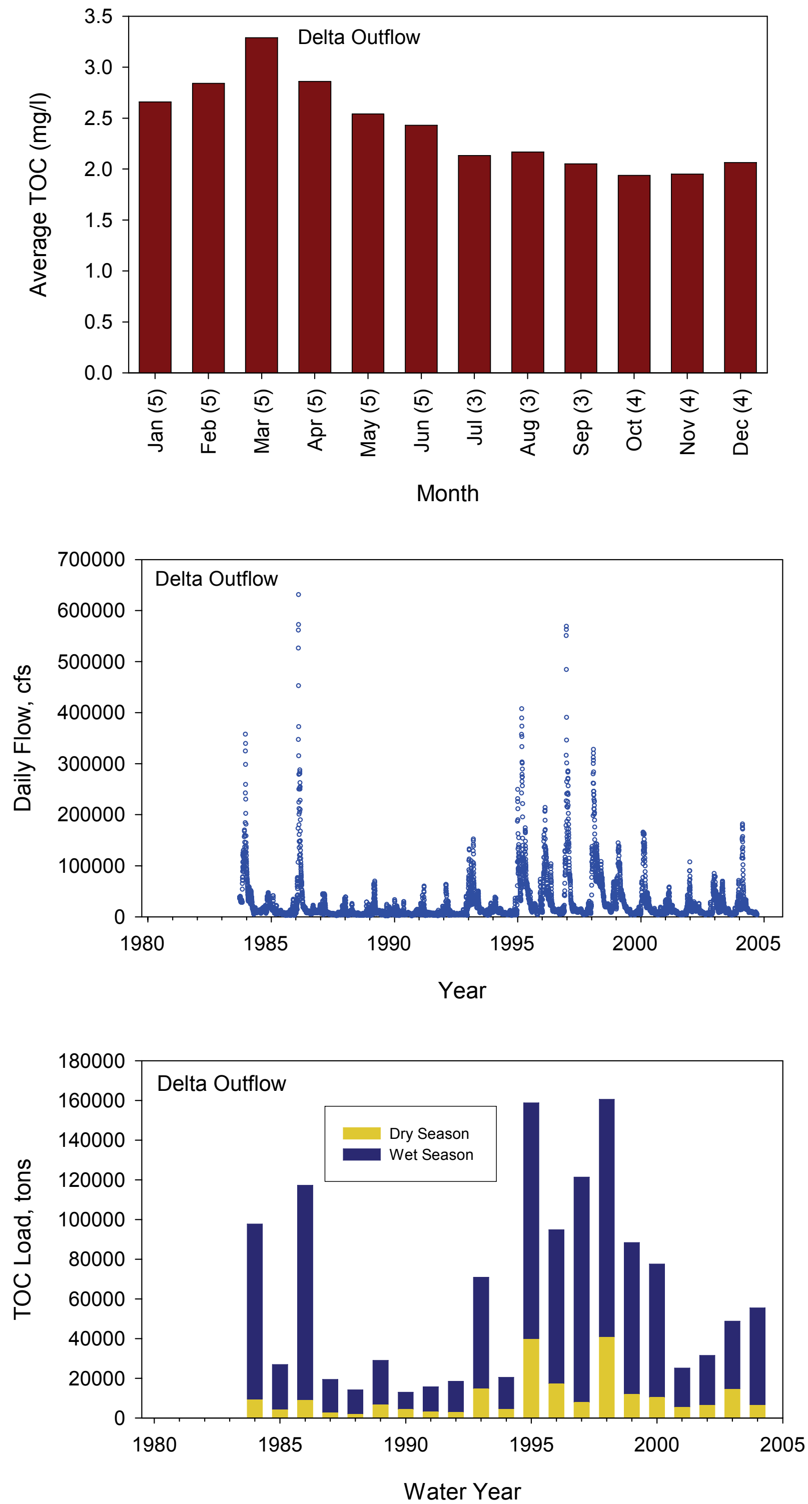

Figure 4-23. Monthly average concentration, daily discharge, and estimated wet and dry season loads by water year for Delta outflows.

The loads calculated for the key subwatersheds are summarized in Table 4-3 for the dry and wet season of wet and dry years. Loads of organic carbon in the dry and wet season of wet years are shown graphically in Figure 4-24. The graphical representation uses arrow thickness to scale loads, and can be used to compare across seasons and locations. The loads closely follow the pattern for flows shown in Figure 4-5, with the Sacramento River being the dominant source. This is true even though concentrations in the San Joaquin River are generally much higher than in the Sacramento River (Chapter 3). Tributary loads and Delta exports to the Bay during wet years are several times higher than during dry years.

Estimated loads from this study compare favorably with loads estimated in previous studies, as shown in Table 4-4. At the Sacramento River (either Freeport or Greene's Landing), loads from Saleh et al. (2003) for wet years and Woodard (2000) for wet and dry years are within 15% of the estimates from this study. At the San Joaquin River at Vernalis, wet and dry year loads from Woodard (2000) are within 30% of current estimates.

Table 4-3.
Loads transported at locations corresponding to the outflow points of the subwatersheds in Table 4-1.

			Dry Years (tons)			Wet Years (tons)			Export Rates (tons/km^2)	
ID	**Watershed Name**	**Upstream Area (km^2)**	Dry Season	Wet Season	Total	Dry Season	Wet Season	Total	Dry year	Wet Year
1	Sacramento River above Bend Bridge	23,144	5,384	6,858	12,242	6,648	20,069	26,717	0.53	1.15
2	Butte Creek	2,402	-	-	-	-	-	-	-	-
3	Sacramento River at Colusa	36,807	4,782	11,612	16,394	6,960	23,530	30,490	0.45	0.83
4	Yuba River	3,502	328	1,096	1,424	1,374	4,530	5,904	0.41	1.69
5	Feather River	9,994	-	-	-	5,975	21,462	27,437		2.75
6	Cache Creek	3,112	9	295	304	131	2,442	2,574	0.10	0.83
7	American River	5,528	2,002	1,876	3,878	3,761	7,320	11,081	0.70	2.00
8	Sacramento River at Hood/Greene's	61,316	9,958	29,355	39,313	18,215	54,382	72,598	0.64	1.18
9	Cosumnes River	2,390	132	339	471	845	1,710	2,555	0.20	1.07
10	San Joaquin River at Newman	19,085	1,136	2,307	3,444	7,117	15,031	22,148	0.18	1.16
11	Stanislaus River	3,478	636	664	1,301	1,367	2,220	3,587	0.37	1.03
12	Tuolumne River	4,586	428	719	1,147	3,057	3,555	6,612	0.25	1.44
13	Merced River	3,289	218	436	653				0.20	-
14	Bear Cr/Owens Cr/Mariposa Cr/Deadmans Cr	2,397	-	-	-	-	-	-	-	-
15	Chowchilla River	850	-	-	-	-	-	-	-	-
16	San Joaquin River at Sack Dam	11,667	673	384	1,057	-	-	-	0.09	-
17	Mokelumne River	3,022	238	311	550	776	1,716	2,492	0.18	0.82
18	Bear River	1,229	19	223	242	105	1,598	1,703	0.20	1.39
19	Putah Creek	1,795	-	-	-	-	-	-	-	-
20	Delta North	2,148	-	-	-	-	-	-	-	-
21	Delta South	5,730	-	-	-	-	-	-	-	-
22	San Joaquin River at Vernalis	32,782	2,222	4,908	7,130	9,237	20,821	30,059	0.22	0.92
-	Yolo Bypass	-	328	2,621	2,949	1,347	37,965	39,312	-	-
-	**Delta Outflow Loads**	**-**	**4,612**	**19,869**	**24,481**	**17,741**	**85,861**	**103,601**	-	-

Note: Loads for watersheds without data in this table are presented in Tables 4-9 and 4-10 for dry and wet years, respectively, as estimated using export rates.

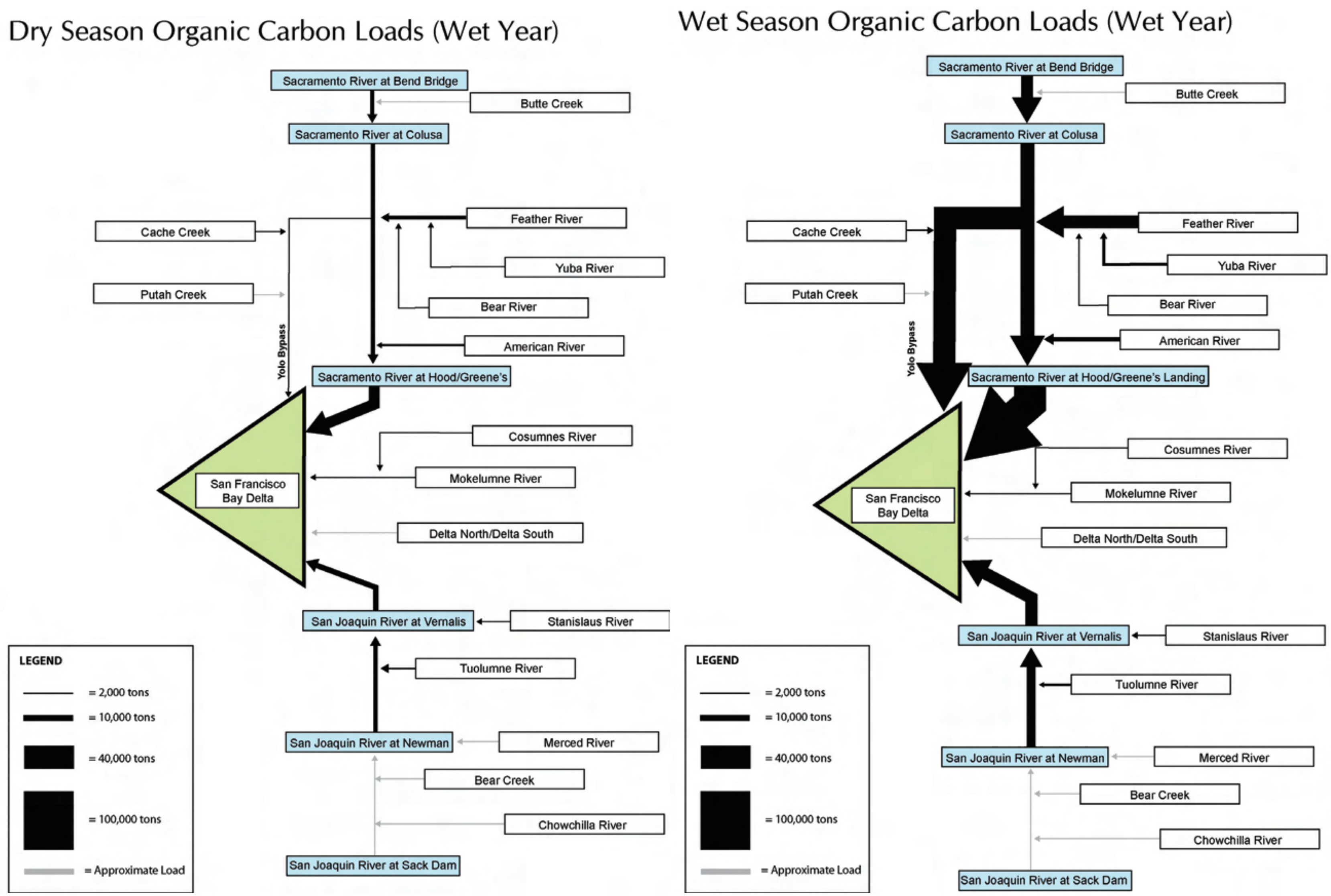

Figure 4-24. Organic carbon loads for the dry and wet season of an average wet year on a schematic representation of the San Joaquin-Sacramento River systems. In-Delta nutrient sources and sinks are presented in Chapter 5.

Table 4-4.
Estimated Loads from this study compared with other published studies (Saleh et al., 2003; Woodard, 2000)

		This Study (tons)		Saleh et al., 2003[1] (tons)	Woodard, 2000; Data from 1980-1999 (tons)	
ID	Watershed Name	Dry Years	Wet Years	Wet Years (Sac: 95-98; SJ: 86-94)	Dry Years	Wet Years
1	Sacramento River above Bend Bridge	12,242	26,717	30,564	-	-
2	Butte Creek	-	-	-	-	-
3	Sacramento River at Colusa	16,394	30,490	32,687	-	-
4	Yuba River	1,424	5,904	7,247	-	-
5	Feather River	-	27,437	40,614	-	-
6	Cache Creek	304	2,574		-	-
7	American River	3,878	11,081	9,996	-	-
8	Sacramento River at Hood/Greene's	39,313	72,598	82,658 [2]	34,697	72,966
9	Cosumnes River	471	2,555	-	-	-
10	San Joaquin River at Newman	3,444	22,148	-	-	-
11	Stanislaus River	1,301	3,587	4,180	-	-
12	Tuolumne River	1,147	6,612	3,904	-	-
13	Merced River	653	-	5,206	-	-
14	Bear Cr/Owens Cr/Mariposa Cr/Deadmans Cr	-	-	-	-	-
15	Chowchilla River	-	-		-	-
16	San Joaquin River at Sack Dam	1,057	-	-	-	-
17	Mokelumne River	550	2,492	-	-	-
18	Bear River	242	1,703	-	-	-
19	Putah Creek	-	-	-	-	-
20	Delta North	-	-	-	-	-
21	Delta South	-	-	-	-	-
22	San Joaquin River at Vernalis	7,130	30,059	17,284	4,844	23,633
	Yolo Bypass	2,949	39,312	-	-	-

[1]Actual loads in this column are based on a personal communication from C. Kratzer, 2005.

[2]Data from Sacramento River at Freeport.

4.4 ALTERNATE METHODS FOR LOAD ESTIMATION

The USGS, in the LOADEST model for computing flux in streams, provides options for alternate formulations for regression equations, nine of which are shown in Table 4-5. Because this general approach has been used in several published reports (Crawford, 1991; Cohn et al., 1992), it was applied in this work to compare results with those presented in Table 4-3. Regression models with multiple fitted coefficients are most appropriate when there are sufficient data to fit. A station with adequate data, the Hood/Greene's Landing station on the Sacramento River, was therefore employed for this comparison.

Loads were computed using the 9 models in Table 4-5 that were applicable to the Hood/Greene's Landing station data, and calculations were performed in a manner consistent with that presented in Section 4-3, i.e., loads were computed for all years and for wet and dry seasons. The results, including the upper and lower confidence intervals of the load estimates (5^{th} and 95^{th} percentile), are presented in Table 4-6. The mean loads for all years (39,000 – 53,000 tons/year) is in the middle to low end of the range of the wet and dry year loads for the Hood/Greene's Landing station on the Sacramento River computed in Section 4-3 (39,300 tons for dry years and 72,600 tons for wet years). This comparison lends credence to the relatively simple method used in the previous section of using the monthly average concentrations and flows. It is recognized, however, that for sites with enough flow and concentration data, the LOADEST approach may provide additional information that is useful, especially the upper and lower confidence limits.

Table 4-5.
Regression equations from the LOADEST program (Runkel et al., 2004).

LoadEst Model	Regression Model of Load
1	$a_0 + a_1 Ln\,Q$
2	$a_0 + a_1 Ln\,Q + a_2 Ln\,Q^2$
3	$a_0 + a_1 Ln\,Q + a_2 d_{time}$
4	$a_0 + a_1 Ln\,Q + a_2 Sin\left(2\pi d_{time}\right) + a_3 Cos\left(2\pi d_{time}\right)$
5	$a_0 + a_1 Ln\,Q + a_2 Ln\,Q^2 + a_3 d_{time}$
6	$a_0 + a_1 Ln\,Q + a_2 Ln\,Q^2 + a_3 Sin\left(2\pi d_{time}\right) + a_4 Cos\left(2\pi d_{time}\right)$
7	$a_0 + a_1 Ln\,Q + a_2 Sin\left(2\pi d_{time}\right) + a_3 Cos\left(2\pi d_{time}\right) + a_4 d_{time}$
8	$a_0 + a_1 Ln\,Q + a_2 Ln\,Q^2 + a_3 Sin\left(2\pi d_{time}\right) + a_4 Cos\left(2\pi d_{time}\right) + a_5 d_{time}$
9	$a_0 + a_1 Ln\,Q + a_2 Ln\,Q^2 + a_3 Sin\left(2\pi d_{time}\right) + a_4 Cos\left(2\pi d_{time}\right) + a_5 d_{time} + a_6 d_{time}^2$

$a_0, a_1, \ldots a_6$ = unknown regression coefficients
Q = streamflow
d_{time} = decimal time

Table 4-6.
Calculated loads at Sacramento River at Hood/Greene's Landing (mean and upper and lower confidence intervals - 5% and 95%), using the 9 regression equations in Table 4-5.

		All Years (tons)		
		Dry Season	Wet Season	Total
	Lower	15,878	33,818	49,906
Model 1	**Mean**	16,574	35,586	52,169
	Upper	17,295	37,422	54,505
	Lower	15,875	34,579	50,702
Model 2	**Mean**	16,568	36,604	53,181
	Upper	17,286	38,715	55,746
	Lower	13,354	28,849	42,293
Model 3	**Mean**	14,846	32,044	46,895
	Upper	16,457	35,493	51,859
	Lower	12,921	37,473	50,907
Model 4	**Mean**	13,603	39,360	52,976
	Upper	14,313	41,319	55,108
	Lower	13,117	29,356	42,599
Model 5	**Mean**	14,570	32,567	47,143
	Upper	16,140	36,029	52,038
	Lower	12,942	37,535	50,976
Model 6	**Mean**	13,635	39,510	53,159
	Upper	14,356	41,563	55,407
	Lower	10,993	32,163	43,373
Model 7	**Mean**	12,170	35,406	47,585
	Upper	13,435	38,885	52,093
	Lower	10,976	32,218	43,409
Model 8	**Mean**	12,148	35,457	47,618
	Upper	13,412	38,932	52,115
	Lower	8,170	23,456	31,715
Model 9	**Mean**	10,012	28,777	38,796
	Upper	12,144	34,942	46,986
This Study (Dry Years)		9,958	29,355	39,313
This Study (Wet Years)		18,215	54,382	72,598

4.5 ESTIMATION OF WATERSHED LOADS

Stream loads calculated above can be compared with loads originating in the watershed that include non-point sources (principally different land uses, such as agriculture, urban land, wetlands, and other natural lands), and point sources (principally wastewater treatment, although other sources may be contributors). The sections below discuss the approach used to estimate these contributions. These are preliminary estimates due to the limited data that were available on export rates from individual land uses.

4.5.1 ESTIMATION OF ORGANIC CARBON EXPORT RATES FROM NON-POINT SOURCES

Non-point source contributions of organic carbon loads to streams are expressed as mass of carbon delivered to the stream per unit area per unit time. The stream outflow represents the load contributions in surface runoff as well as baseflow (i.e., through groundwater). The export rate calculations are similar to the load estimates from streams except that for the rates to be applicable to one type of land use, the watershed in consideration must contain only that land use. Thus, an urban land organic carbon export rate is obtained from a watershed that is entirely urban land, and a background export rate is obtained from a watershed with minimal development. In practice, finding watersheds with only one type of land use is very difficult, although in some instances small indicator watersheds may be found that fit this criterion. Export rates from specific land uses, weighted by the area of that land use in a watershed, can be used to compute the non-point source contribution, as shown schematically in Figure 4-25.

Organic carbon export rates were estimated for urban land and agricultural land in the San Joaquin and Sacramento Basins, background loads from a mix of forest and shrubland (or rangeland), and from wetlands. Further stratification of land use-based export rates (e.g., by crop type for agricultural land) was not possible given the existing data. This is an area that will benefit greatly through collection of additional data in small indicator watersheds as described in Chapter 6.

The following locations were used to develop preliminary export rates:

- The Colusa Basin Drain was used for estimating agricultural loads in the Sacramento River Basin as shown in Figure 4-26. Although the Colusa Basin Drain watershed includes non-agricultural land, it was the best station based on the existing data. Harding Drain was used for agricultural loads in the San Joaquin Basin as shown in Figure 4-27.

- Mud Slough and Salt Slough were used for estimating wetland loads in the San Joaquin Basin as shown in Figures 4-28 and 4-29.

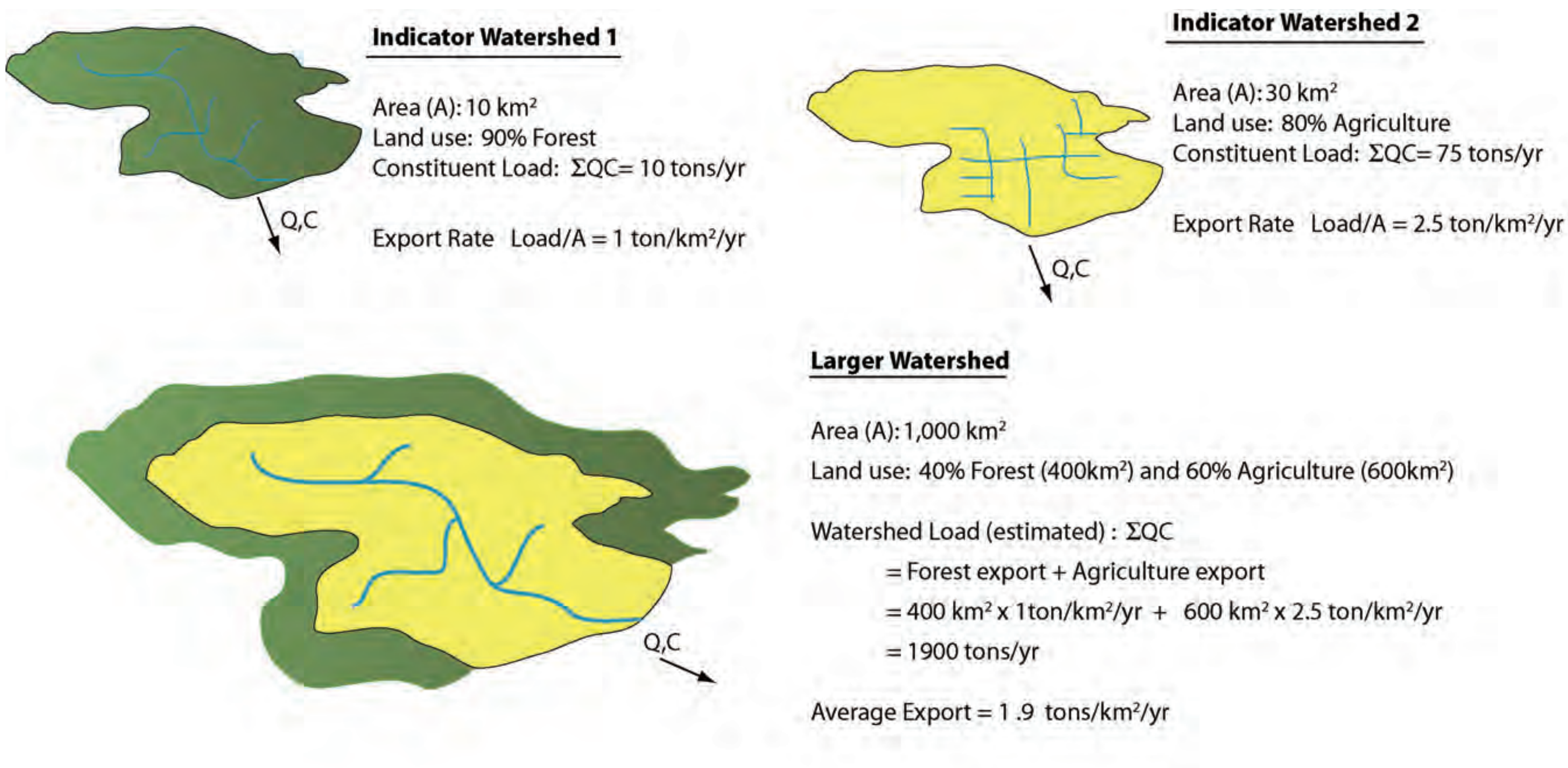

Figure 4-25. Export rates from specific land uses, weighted by the area of that land use in a watershed, can be used to compute the non-point source contribution for a mixed land use watershed.

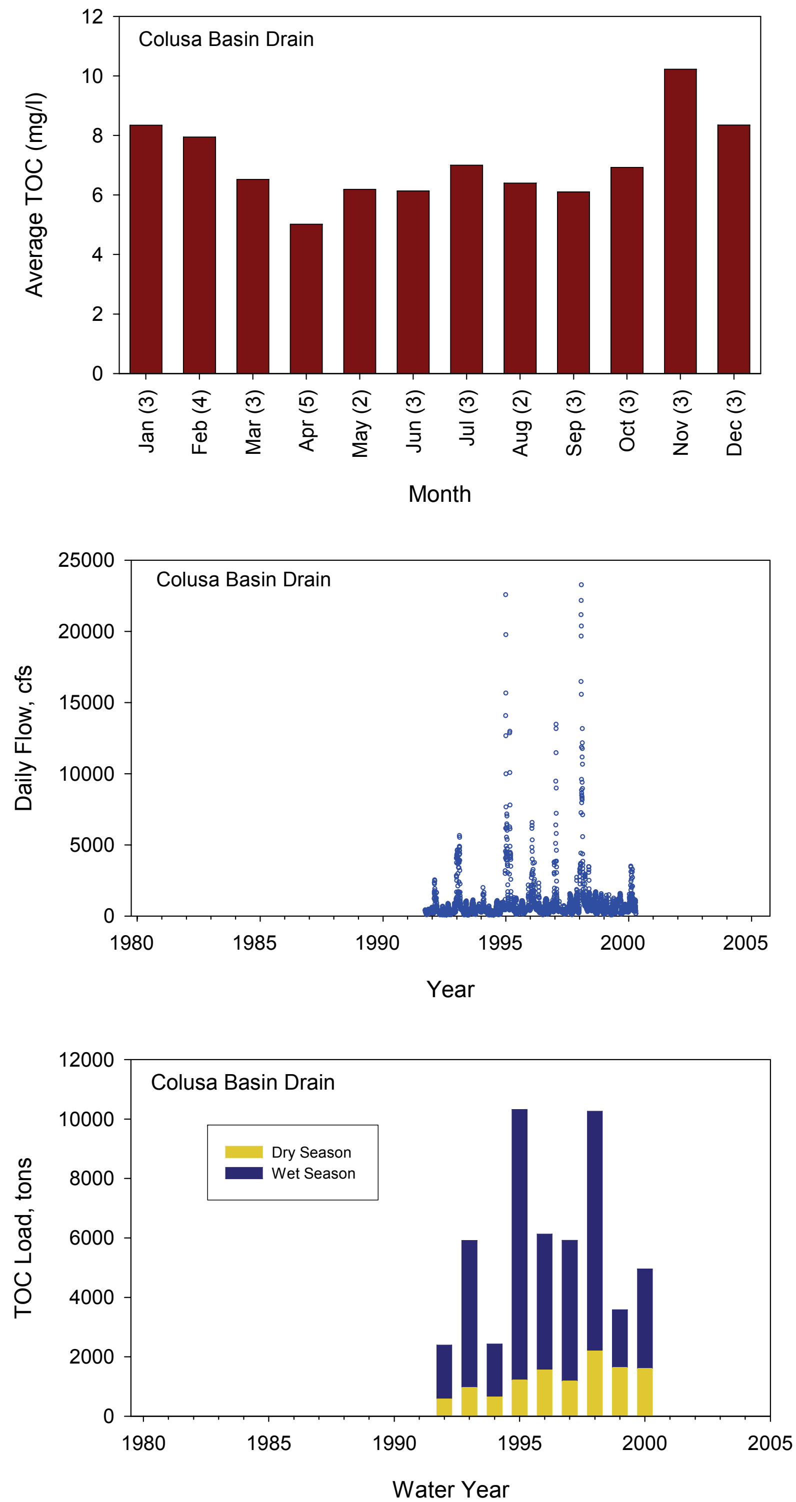

Figure 4-26. Monthly average concentration, daily discharge, and estimated wet and dry season loads by water year for the Colusa Basin Drain. These data were used to estimate the organic carbon export rate from agriculture in the Sacramento River basin.